OMAR YAGHI'S GLOBAL JOURNEY

From the abstract to the practical

Omar Yaghi was born in Amman, Jordan, in 1965. His homeland is a quiet country of 6.5 million people bordered by Saudi Arabia, Iraq, Syria and Israel. The country, currently a humanitarian refuge for nearly a million Syrian refugees, is effectively ruled and economically prosperous.

Quiet, effective, humanitarian—those words could be used to describe Yaghi as well. He says, "As one of several children in an active household, I had an independent personality, and my family left me alone from an early age to observe the world."

"When I was in ninth grade," he continues, "my father told me I was going to study in the United States. I said no. As an alternative, I could have gone to Russia, studied medicine and earned an M.D. on a full scholarship. I had to choose. I finally decided to come to the United States.

"I stayed with a retired couple with an extra room in their house. It was in Troy, NY, and I was 15. An older brother who was already in the area took me to Hudson Valley Community College. The adviser asked me a few questions, which I attempted to answer in my limited English.

"The school wouldn't admit me, but I was allowed to take classes. I took mostly science and math courses, did very well, and returned to the admissions office at the end of the semester. They let me enroll.

"I later transferred to SUNY Albany to finish my undergraduate degree. I have never enjoyed lectures, but I was diligent and went to class. I learned a lot on my own. For me, the chemistry lab was a safe haven. There I discovered a hidden world, and I began to investigate this world, which is quite alive."

In the fall of 1985, Yaghi arrived at the University of Illinois at Urbana-Champaign as a chemistry graduate student. There he studied inorganic chemistry with Walter Klemperer.

Says Yaghi, "With me, Klemperer had to start with a diligent but unpolished mind. I was only 20 when I went to graduate school, and I was an explorer, a dreamer. The rigors of science did not come naturally. Klemperer taught me to make quantitative measurements. He did not settle for less than perfection.

"I spent a whole year attempting to accomplish a deprotonation reaction. I finally put the results into an NMR instrument, but they were not what I expected. I thought I had failed. I was very upset. I went to Klemperer, nearly in tears. He calmly looked at the data and said it looked like I had found some interesting new compounds. He suggested I get to work purifying them and figuring out what they were.

"So that's what I did. I purified one, and the result was a brown muck. My lab mates suggested I throw it away. But I dissolved it in a solvent and left it overnight, and when I came back it had formed a beautiful crystal. This was the beginning of the study of the polyoxovanadates as the first examples of inorganic cavitands—container-shaped molecules that allow host-guest reactions."

In 1990, Ph.D. in hand, Yaghi left for a postdoc at Harvard with chemist Richard Holm. Yaghi's grad school mentor Klemperer had taught him that "Science starts with doubt." But according to Richard Holm, his postdoc mentor, "Science is an exercise in optimism."

"I had two mentors with two different useful ways of approaching science. For me the contradiction was character forming. How do you produce your own way to view the world? From Klemperer I had learned to make clusters from their chemical building blocks. With Holm I learned to make extended solids and break them down to excise out clusters you couldn't make any other way. First I learned to make things bottom up, then top down."

Yaghi started his academic career at Arizona State in 1992, where he quickly established a successful research program that has continued to grow for 20 years. He moved on to the University of Michigan, then UCLA, and in 2012, UC Berkeley and LBNL.

His work can be briefly summarized by three acronyms—MOFs, ZIFs and COFs—metal organic frameworks, zeolitic imidazolate frameworks and covalent organic frameworks. These three basic frameworks can produce almost an infinite number of structures.

Although Yaghi pursued these frameworks at first purely as an intellectual enterprise, they have proven to be very useful. The structures are super-porous, with surface areas up to 11,000 square meters per gram. Due to their extremely low weight and high surface area, they can trap and hold high volumes of gases.

The German chemical company BASF has developed a MOF fuel tank for natural gas-powered vehicles that allows more fuel to be stored on-board. This technology should be commercially available in the next few years. Yaghi is developing other MOFs that may allow practical on-board hydrogen storage for fuel cell vehicles.

Along with chemistry department colleague Jeff Long and CBE colleagues Berend Smit and Jeff Reimer, Yaghi is working to classify and characterize molecular structures that can capture the carbon dioxide produced by burning fossil fuels. Yaghi and his students are working to expand the pore size of structures so that they can accommodate proteins, creating the possibility of biological applications.

The building block approach he developed has led to an explosive growth in the creation of new materials. Yaghi calls this emerging field "reticular chemistry." He is listed among the top ten most highly cited chemists worldwide, and he has won several awards for the development of new materials.

In addition to making new materials that the world has never seen before, Yaghi is also creating new research models to address global problems. He says, "Americans are good mentors. The unqualified passing on of knowledge is unique and makes America an innovative country.

"The world now faces immense problems that don't know borders, and yet all over the world there are so many people who don't have the opportunity to develop their minds. As an educator, I have been asking myself how can I change this situation? How can I share America's mentoring style with the rest of the world? Higher education, like trade and commerce, needs to become global."

For Yaghi, the solution has been to form research centers that function as satellite labs. He has created three such collaborations, at the National Institute of Materials (NIMs), in Tsukuba, Japan; the Korea Advanced Institute of Science and Technology (KAIST) in Daejeon, Korea; and the Vietnam National University in Ho Chi Minh City (Saigon), Vietnam.

Yaghi says, "When I was a young man, chemistry was a refuge from the world where I could study abstract problems. I have been lucky that my ideas have found practical applications in my lifetime. Now I find myself traveling around the world to work with other researchers.

"I've learned that chemistry can be lots of fun if you're willing to accept failure—you fail, you fail, you fail, then you succeed. How sweet it is when that happens! I've been a professor for over 20 years and I am constantly failing along the road to discovery. No other job has such a tolerance level for failure. Science is a special profession."